10/532553
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JC20 Rec'd PCT/PTO 22 APR 2005

Vehicle tyre

The invention relates to a vehicle tyre having a body of elastic material, particularly of rubber or poly-urethane, provided with a crown portion containing the running surface, comprising two sidewalls joined to the crown portion by shoulder portions and ending in beads, as well as radially arranged leaf springs in specified distances from one bead to another, and the beads are clamped into a wheel rim.

The vehicle tyre according to the invention can be used advantageously with every vehicle having vehicle tyres including trucks, military vehicles, cars, etc.

Vehicle tyres currently used are in general pneumatic tyres, which means that to carry the load acting on the tyres, overpressure is necessary in the tyres.

Vehicle tyres working with internal overpressure function well in practice, however, their significant draw-backs are that

- they have a complex structural design,
- the preparation for their serial production is complicated, it needs much living work and investment,
- they are very unsafe in case of a puncture during their functioning (in the first line on public roads).

The patent No. US 1,610,238 tries to realize a vehicle tyre without overpressure, in which round springs bent into a circle are built in radially, and a spring running around the circumference of the tyre is thread into a loop situated on the crown portion of the tyre. The ends of the springs are bent into a ring on the bead portions, into which ring a ring-shaped spring of a diameter identical with that of the bead of the tyre is thread.

Similarly, radially situated and ring-shaped leaf springs are described in the patent No. US 1,113,036, however, with the difference that in this solution the springs do not contain a loop on the crown portion.

According to the patent No. US 1,471,580, springs prepared from wires of circular cross-section are built in in a tunnel-like way, which tunnel consists of two-two symmetrically situated semi-circles joining each other.

Both spring-ends are provided with a fold-back of the form of a whole circle. Into these whole circle-shaped fold-backs a steel-wire is thread, which plays the role of the bead-ring.

In the circumferential direction, the radial springs are tied-up in pairs by a reinforcement on the crown portion. In this solution, overpressure is applied to ensure the necessary loadability.

The disadvantage of the solutions described is that the tyre is unsuitable for the drift correction of a load of 200–300 kg or more, as the circular cross-section becomes flat, and due to the large deformation, the springs fatigue and break. Another draw-back of the vehicle tyres of such construction is that they can be used only on vehicles with low travelling speeds (maximum 40–50 km/h). In case of larger load or speed, the temperature of the vehicle tyres significantly exceeds the acceptable temperature limit of 80–90 °C due to large spring deformations. As a consequence, the rubber material ages very quickly becoming thereby unsuitable for further use. A further disadvantage of the above solutions is the small side stability characteristic for the high profiles, which makes their safe operation in today's high-speed vehicles impossible.

The object of the patent No. US 6,374,887 is a vehicle tyre without overpressure reinforced by leaf springs made of an elastic material, preferably of rubber or rubber-like material, provided with a crown portion containing the running surface, and comprising two side-walls joined to the crown portion via shoulder portions, the two sidewalls end in beads which are clamped into a wheel rim. The crown portion, sidewalls and the beads are kept together by ribs made of an elastic material, which are supported by arched leaf springs. The ends of the leaf springs are embedded flexibly into the beads, and the whole vehicle tyre is mounted onto the wheel rim in a pre-stressed state. The disadvantages of this solution are:

- The strengthening ribs slip on the leaf springs during functioning, since the leaf springs are not built into the rubber body of the tyre. The friction thus generated results in heat generation, as a consequence of which is a strong heating-up of the tyre.
- Owing to the flexible embedding of the leaf spring ends into the beads, they also heat up the beads strongly during operation due to the large deformation of the tyres.
- Under a high loading of the tyres, the spring ends are pressed into the rubber material of the beads, thus the bead ends of the spring mutually near each other and move away from each other, and as a result, fold-like peak deformations are generated on the crown portion of the springs. These peak deformations result in breaking of the springs in a short time of operation.

The task to be solved by the invention is to develop vehicle tyres of high resistance, loadability, speed and side stability, eliminating, or at least reducing the above disadvantages of known vehicle tyres.

The invention is based on the recognition that the disadvantages of known vehicle tyres with leaf springs originate mainly from the shape and arrangement of the leaf springs, and from the mode of their joining with the rubber body of the tyres.

In order to solve this task, a vehicle tyre type made of an elastic material, preferably of rubber or poly-urethane is developed having a body provided with a crown portion containing the running surface, two sidewalls joined to the crown portion via shoulder portions and ending in beads, as well as radially placed leaf springs situated in specified distances from each other and extending from one bead till the other, and the beads are clamped into a wheel rim. According to the invention, the leaf springs are embedded at least along the crown portion and the beads into the body made of an elastic material, where the leaf springs have inwardly bent leaf spring ends. The shape of the leaf springs in the angular range of $0 \leq t \leq \pi$ from the one bead to the other, can be described in an orthogonal coordinate system with axes

X and Y by coordinates as $x = a \cdot \cos t$ and $y = b \cdot \sin t$. This shape is semi-elliptical, where the semi-ellipse falls inside the range determined by ellipses

$$\frac{7}{8}a \geq b \geq \frac{1}{2}a$$

where

a is the half of the large axis of the ellipse,

b is the half of the small axis of the ellipse.

In the ideal case:

$$b = \frac{2}{3}a$$

If it is desirable to increase further the flexibility and dynamic life time of the leaf springs, it is preferable to build the springs from a number of thin spring plates, if necessary, with the insertion of some binding material.

In case of a normal, that is one-piece wheel rim, the angle between the inwardly bent leaf spring ends of the leaf springs and the X axis of the orthogonal coordinate system, α, is minimum 8°, or preferably it is equal to the angle between the wheel rim portion fitting to the bead of the tyre and the rotation axis of the wheel rim. In this case, the leaf springs on the crown portion should be covered in the circumferencial direction by two high-strength, low-strech belt inserts with good dynamic properties built completely into the rubber. A rubber layer of a thickness of at least 2 mm should be between the belt insert and the leaf springs.

For a slip-free fixing of the tyres on the wheel rim, it is necessary to have a length of the leaf spring ends of minimum 10 mm, and its whole surface should be embedded into the rubber.

Considering the allowed rubber deformation, a free rubber surface of a breadth of 10 mm should be ensured in the crown portion between the leaf springs.

In case of a two-piece, dismountable wheel rim, the angle between the leaf spring ends and the X axis should be minimum 8°, and preferably it is identical with the angle between the wheel rim portion fitting to the bead of the tyre and the rotation axis of the wheel rim.

It is preferable if the ends of the leaf springs in side-view show a horizontal C-shape, where in the nest formed by the C-shape, a bead-ring is embedded into the rubber body of the beads.

The circular bead-ring is made of high-strength steel (min. 60 kp/mm^2) or of circularly bent, stranded spring steel wires embedded into rubber, or preferably of Kevlar reinforced possibly by graphite or glass fibres, etc.

It is preferable if the surface of the leaf springs is treated with some material facilitating adhesion, preferably with the two-component CHEMOSIL solution, or if a copper covering is applied.

It is expedient to cover the leaf springs under the running surface with a rubber-coated strengthening material, e.g. by Kevlar fabric.

It is further preferable to apply belt inserts provided with some strengthening material above the leaf springs, e.g. steel-cord inserts or Kevlar fabric inserts.

The invention will be described in more detail on the basis of preferred embodiments, by referring to the following drawings:

Figure 1 shows the section of a possible embodiment of a vehicle tyre according to the invention mounted onto a one-piece wheel rim.

Figure 2 is a section of a possible embodiment of a vehicle tyre according to the invention mounted onto a two-piece wheel rim.

Figure 3 is a diagram showing the shape of the leaf springs in the vehicle tyre according to the invention.

Figure 4 is the section around the circumference of a possible embodiment of the vehicle tyre according to the invention.

Figure 5 shows the radial section of a possible embodiment of the vehicle tyre according to the invention under and without load.

Figure 6 is an axonometric section of a possible embodiment of the vehicle tyre according to the invention.

Figure 1 shows a preferred embodiment of vehicle tyre 1 according to the invention, the body of which is made of an elastic material, especially of rubber or poly-urethane e.g. by dye-casting (injection moulding), the tyre body 1 having a crown portion 1.1 provided with the running surface and adjacent two sidewalls 1.3 joined to the crown portion via shoulder portions 1.2 and ending in beads 1.4.

The beads 1.4 of the vehicle tyre are clamped into a one-piece wheel rim 5. Vehicle tyre 1 contains further radially arranged leaf springs 2. The material of leaf springs 2 may be of single-layer or multi-layer spring steel, graphite or Kevlar with graphite or glass fibre reinforcements, etc.

Between leaf springs 2, a free rubber surface of at least 10 mm breadth should be situated in the crown portion 1.1.

Above leaf springs 2, belt insert 3 embedded into rubber is built in, the material of which may be e.g. some high-strength rubbered fabric or a cable containing Kevlar, steel, etc. cords situated in an angle of minimum 10° to the central line of the crown portion 1.1. This Kevlar fabric allows the pre-stressed mounting of vehicle tyre 1 on wheel rim 5, which ensures protection of the vehicle tyre 1 at breaking, or at a higher travelling speed (160–200 km/h) protects against expansion due to centrifugal force, hindering thereby the slip of beads 1.4 on wheel rim 5.

Leaf spring ends 4 of leaf springs 2 are back-folded. The back-folded leaf spring ends 4 rest against wheel rim 5. For this purpose, grooves are developed on wheel rim 5. Leaf springs 2 are covered by rubber at beads 1.4 and in the internal sides of sidewalls 1.3, and on the internal section 6 of crown portion 1.1. In order to ensure better heat conductivity, leaf springs 2 may remain uncovered from below on the internal section 7 of shoulder portion 1.2. Leaf springs 2 are covered with a material ensuring better metal-rubber adhesion in order to facilitate appropriate building in into the rubber. This may be one- or two-component CHEMOSIL, or a brass covering, etc.

The metal-rubber adhesion can be further improved by covering the surface of leaf spring 2 after the above mentioned teatment with metal-rubber adhesion improving material with a rubbered fabric (preferably with Kevlar). The running surface of vehicle tyre 1 contacting directly with the road is developed above belt inserts 3 in the rubber layer 8 so that it is provided with a tread pattern.

In Figure 2, a vehicle tyre 1 mounted to a two-piece wheel rim 12, 13 can be seen. The ends of leaf springs 2 built into vehicle tyre 1 are bent into a lying (horizontal) C-shape. In the nest formed by the C-shape, in both beads 1.4, bead-rings 9 are placed. The foot part 10 of back-folded leaf springs 2 rest against the wheel rim, its ends 11 hinder the sliding out of bead ring 9 from the bead 1.4 of vehicle tyre 1 due to this back-folding. The whole of bead rings 9 and leaf springs 2 is embedded into rubber. In the inside of vehicle tyre 1, leaf springs 2 are covered by a rubber layer 14, hindering thereby the contact of leaf springs 2 with air moisture and thus their oxidation during functioning.

Figure 3 shows the shape of leaf springs 2 situated in the cross-section of the vehicle tyre 1 in an orthogonal coordinate system with axes X and Y. It is seen in the diagram that point *b* cut out from axis Y by the semi-ellipse 15 and describing the shape of leaf spring 2 falls in the ideal case between points *b'* and *b''*.

Point *b'* is cut out from axis Y by semi-ellipse 17 satisfying the condition $(b' = \frac{1}{2}a)$.

Point *b''* is cut out from axis Y by semi-ellipse 16 satisfying the condition $(b'' = \frac{7}{8}a)$.

Thus the contour of leaf spring 2 in the angular range of $0 \leq t \leq \pi$ (0–180°) corresponds to the ellipse satisfying the following conditions:

$$\frac{7}{8}a \geq b \geq \frac{1}{2}a$$

Semi-ellipses 15, 16 and 17 cut axis X in point a, where $2a$ is the large axis of the ellipses and $2b$, $2b'$ and $2b''$ are the small axes of the ellipses.

In the embodiment according to the invention, the shoulder portion 1.2 of the vehicle tyre 1 can be broader than the bead 1.4 of the vehicle tyre 1 by a factor of $k = \min \frac{2a}{100} \cdot 5$ mm, where the distance of beads 1.4 is identical with two-times the thickness of the rubber layer covering the bead plus $2a$.

The ends of leaf springs 2 are produced with a minimum of $\alpha = 8^o$ break, thus the angle between leaf spring ends 4 and axis X is at least 8^o.

The shock absorption of the vehicle tyre 1 occurs due to the shape change of leaf springs 2 occurring as a result of load.

In case of an elliptical cross-section, the shape change during load is distributed uniformly along the whole length of leaf spring 2, i.e. no stress peaks occur which would lead to breaking, thus a dynamic life time similar to that of vehicle tyres of radial or diagonal cord structure can be ensured.

In this solution, the thin rubber layer covering the bead portion of the vehicle tyre 1 serves only appropriate bearing and the adhesion hindering the slip of the bead 1.4 of the vehicle tyre 1 on wheel rim 5 and does not play any role in the shock absorption of the vehicle tyre 1.

Figure 4 illustrates the mutual arrangement of leaf springs 2 built into vehicle tyre 1. The thickness of leaf springs 2, their breadth A and distance C measured in the crown portion 1.1 and distance B measured at bead 1.4 depend to a great extent on the size of vehicle tyre 1, as well as on the properties expected from the vehicle tyre 1. Considering the dynamic properties of rubber, distance C and dimension A should be minimum 10 mm, whereas distance B has to be minimum 2 mm. If the speed of a 15 ″-sized vehicle tyre is 150 km/h, and its load is 400 kg, for spring steel material, the dimension A of the leaf spring 2 is minimum 20 mm, its thickness is 2 mm, and the distance between leaf springs 2, i.e. C, is minimum 15 mm.

Figure 5 shows the deformation of the rubber body and leaf springs 2 in the vehicle tyre 1 under load. It can be seen that under load, the b

dimension of the semi-elliptical leaf spring 2 is deformed in the crown portion into the curvature 19, its height in the crown portion is reduced to dimension *b''*, whereas the position of the bead 1.4 of leaf spring 2 remains unchanged. Thus, the convex surface 18 of the running surface is deformed to plane 20.

In Figure 6 leaf springs 2 are well seen, the surfaces of which are treated with a two-component CHEMOSIL solution 21 in order to ensure better adherance to the rubber, and on the portion below the running surface they are covered by a rubbered Kevlar fabric 22. Above leaf springs 2, Kevlar belt inserts 3 are situated ensuring the adhesion of the vehicle tyre 1 to wheel rim 5, even in case of a high travelling speed.

Experiments showed that the deformation of leaf springs 2 built into the vehicle tyre 1 under load is most uniform, which means that in case of fixed bead 1.4 of leaf springs 2, the whole leaf spring 2 is uniformly deformed under load, i.e. no deformation peaks are generated. Namely, where deformation peaks appear, in case of dynamic stress, after a short life-time a breakage occurs. The solution according to the invention increases significantly the life-time of vehicle tyres.

The most significant advantages of the vehicle tyres according to the invention are:

- Total safety at punctures, since the vehicle tyre does not have internal overpressure, thus no overpressure can escape which would deteriorate the travelling properties.
- Simple die-casting techniques can be applied for manufacturing.
- The product can be prepared with low cost, at small places, in big series.
- The manufacturing process is well automatable, the production quality is reliable.
- No constant control of overpressure is necessary in the vehicle tyre.
- There is no need for a spare tyre.
- The energy requirement of the manufacturing of vehicle tyre according to the invention is lower, thus less environmental harm is caused.

List of reference numbers

1	vehicle tyre
2	leaf spring
2a	size
3	belt insert
4	leaf spring end
5	one-piece wheel rim
6	section
7	section
8	rubber layer
9	bead-ring
10	socket portion
11	end
12	two-piece wheel rim
13	two-piece wheel rim
14	rubber layer
15	semi-ellipse
16	semi-ellipse
17	semi-ellipse
18	convex surface
19	curvature
20	rail
21	solution
22	Kevlar fabric
b	point
b'	point
b''	point